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THE WETTING OF COMBAT BOOTS - WET GRASS VERSUS PUDDLES.(U)
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THE WETTING OF COMBAT BOOTS – WET GRASS VERSUS PUDDLES

by

R.M. Crow and M.M. Dewar
Protective Sciences Division
Environmental Protection Section

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ABSTRACT

Studies described here show that subjects wearing combat boots and socks get their feet wetter when walking through wet grass than through puddles due to the abrasive action of the grass which cuts away the water-repellent outer layer of the boot. Further, it was found that guttated water does not wet new or silicone-coated leather any more than distilled water (dew) and so does not account for the wetting of boots in grass.

RÉSUMÉ

Les études exposées ici révèlent que les sujets portant des bottes de combat et des chaussettes se mouillent plus rapidement les pieds dans de l'herbe mouillée que dans des flaques d'eau, à cause de l'action abrasive de l'herbe sur la couche externe imperméabilisée de la botte. On a également découvert que l'eau guttation ne mouille pas plus le cuir neuf ou enduit de silicone que l'eau de condensation (rosée), et qu'on ne saurait donc lui attribuer le fait que les bottes prennent l'eau losqu'on marche dans l'herbe.

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INTRODUCTION

A comment made by experienced combat soldiers in Canada is that their feet get wetter when walking through dew-covered grass than when walking through rain puddles. At the 1979 Joint US/Cdn Technical Discussions, this subject was raised, and the Americans confirmed hearing the same observations from their soldiers. As a result, a small study was undertaken to confirm, or otherwise, this phenomenon by measuring the amount of moisture pick-up by combat boots and socks when test subjects walked through grass and through puddles.

During the discussion of the subject of whether boots get wetter in grass than in puddles, the process of guttation was mentioned. Guttated water is water which is lost from a plant leaf in liquid form rather than in the usual form of water vapour. This occurs under conditions of high humidity and can be observed as a drop of liquid on the tip of the plant leaf. It was hypothesized that guttated water on grass contains substances which wet the leather of combat boots, even those coated with silicone compounds and that this may account for the differences in wettability of the boots in grass versus rain puddles. A small study was carried out to determine the wetting characteristics of guttated water versus distilled water (representing dew) to determine whether or not there was any difference in the wetting properties of the two.

MOISTURE PICKUP BY BOOTS AND SOCKS - GRASS VERSUS PUDDLES

METHOD

This small study was carried out in August 1981. Four test subjects who participated in the study were active, male military personnel of the Canadian Forces. Prior to the study, they all confirmed the experience of getting wetter feet when walking through grass than through rain puddles when wearing their combat boots.

Although Canada had a new boot on user trial at the time, "Boots, Combat GS, Mark III" were used as these were the boots on which the soldiers' past observations were based. Three of the four pairs of combat boots were used-personal-issue boots and one pair new-personal-issue boots (Subject 4). The socks worn were also personal issue (Socks, Mens, Long) which were 80% wool and 20% nylon with a reinforced heel and toe.

Before the grass tests and before the puddle tests, all boots were coated with silicone (Leather Water Repellent, CF-S-630, Type 2).

Before the first test, the boots and socks were oven-dried at 50°C for two hours and then placed overnight in a plastic garbage container which had been converted to a large desiccator, using 'Drierite' as the drying agent. After each test, the boots and socks were dried in the oven at a temperature no higher than 50°C and at a low humidity setting until they reached their original dry weight. This took from 3 to 5 hours, depending on the amount of moisture in the boots. The boots and socks were placed in the desiccator overnight and weighed immediately before each test.

At approximately 0900 hrs each morning, the test subjects put on their weighed socks and combat boots in the laboratory and walked on a paved road to one of the test sites (approximately 300 metres to the grass test site and 180 metres to the puddle test site).

For the grass tests, the subjects walked at a slow march through a flat area of grass and some weeds which varied from 20 to 60 cm in height, for 30 minutes. They indicated when they felt a foot getting wet. The elapsed time when this occurred was recorded. The ambient temperature 15 minutes into each test was recorded, along with the conditions during the test. At the end of the 30 minutes, the subjects returned to the paved road and to the laboratory from which they had started. They immediately doffed their socks and boots which were immediately weighed.

For the puddle tests, the subjects walked at a slow march on a paved oval circuit of approximately 90 metres for 30 minutes. A sketch of the circuit is given in Figure 1. Hoses continually filled the large puddle and wooden frames with water to maintain water levels. As in the grass tests, the subjects indicated when they felt a foot getting wet.

RESULTS AND DISCUSSION

The night conditions preceding the tests, conditions during the tests and associated comments are given in Table I. The results of moisture pickup by the boots and socks for the tests are given in Tables II and III. Photos of the boots after the grass tests and after the puddle tests are shown in Figures 2 and 3.

It must be pointed out that some of the total moisture pickup would have been sweat from the foot and this would vary from subject to subject. However, a low and constant work rate for approximately the same

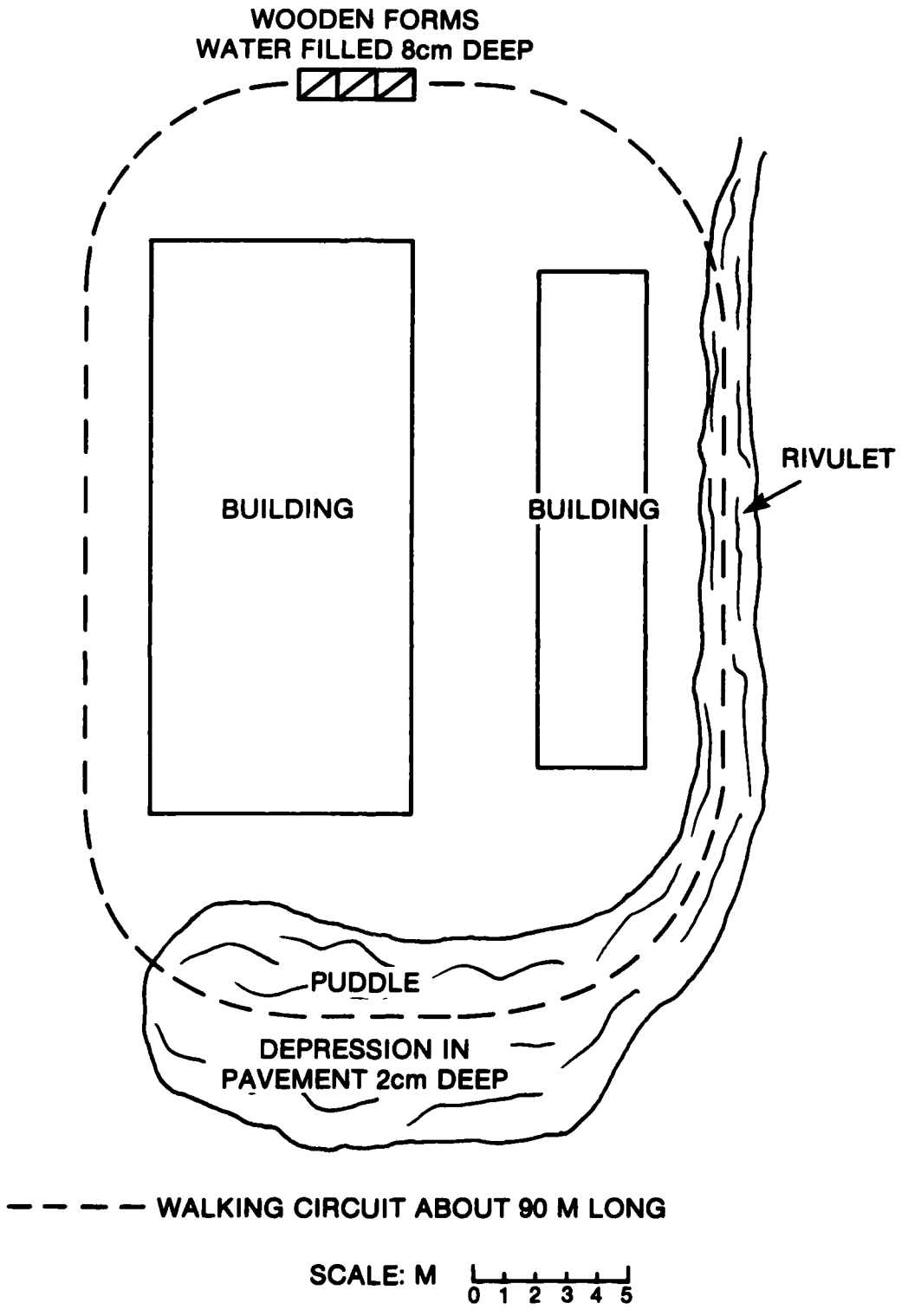

Figure 1: Schematic diagram of walking circuit.

TABLE I

Environmental Conditions and Observations

Grass Tests	Night Conditions Preceding Test	Conditions During Test	Comments
Test 1 August 5	Rainfall of 110 mm during night	19.5°C Same light rain	
Test 2 August 6	Cool and clear	20.5°C Sun, light breeze	Guttated water & dew observed.
Test 3 August 7	Cool and clear	20°C Sun, high cloud Brisk breeze	Toes of boots whitish colour. Guttated water & dew observed.
	(Scattered showers over weekend)		
Test 4 August 10	Fog overnight	22°C Sun and cloud Moderate Breeze	Guttated water & dew observed.
Puddle Tests			
Test 5 August 12	Cool and clear	19°C Sun and clear Brisk breeze	Subjects 3 & 4 walked into water coming from puddle hose on each circuit
Test 6 August 13	Cool and cloudy	18.5°C Overcast Moderate breeze	Subjects did not walk into water coming from hose.
Test 7 August 14	Cool and clear	15°C Sun and clear No breeze	Subjects did not walk into water coming from hose.

TABLE II

Moisture Pickup by Boots and Socks
After Walking Through Grass
(grams)

	Test	Left			Right			Total
		Boot	Sock	Total	Boot	Sock	Total	
Subject 1	1	95	20	115	100	23	123	238*
	2	67	7	74	78	10	88	162
	4	60	4	64	71	8	79	143
Subject 2	1	174	25	199	197	34	231	430*
	2	99	9	108	129	15	144	252
	3	62	5	67	83	7	90	157
Subject 3	1	203	34	237	191	29	220	457*
	2	108	6	114	109	6	115	229
	4	89	5	94	93	5	98	192
Subject 4	2	57	10	67	83	8	91	158
	3	56	12	68	61	6	67	135
	4	82	17	99	101	12	113	212

* 11 cm rainfall preceding night.

Walking Time Before Sensation of Wet Feet
(minutes)

	Test							
	1		2		3		4	
	L	R	L	R	L	R	L	R
Subject 1	15	15	11	22				
2	11	11	9	9	15	15		
3	10	10	12.5	12.5			7	8
4				14	8	8	7	7

L = Left Foot
R = Right Foot

TABLE III

Moisture Pickup by Boots and Socks
After Walking Through Puddles
(grams)

	Test	Left			Right			Total
		Boot	Sock	Total	Boot	Sock	Total	
Subject 1	5	36	3	39	36	4	40	79
	6	23	1	24	22	2	24	48
	7	25	2	27	30	3	33	60
Subject 2	5	58	3	51	83	4	87**	138
	6	35	2	37	55	2	57**	94
	7	34	2.5	36.5	51	2.5	53.5**	90
Subject 3	5	104	4	108	99	11	110	218*
	6	32	1	33	39	3	42	75
	7	33	3	36	41	3	44	80
Subject 4	5	69	9	78	85	15	100	178*
	6	29	3	32	23	2	25	57
	7	31	3	34	30	3	33	67

* Water entered at tongue and laces. Tongue and socks soaked in this area.

** Leak in boot.

Walking Time Before Sensation of Wet Feet
(minutes)

	Test					
	5		6		7	
	L	R	L	R	L	R
Subject 1	19	24	-	-	-	-
2	25	26	-	-	-	-
3	16	16	-	26	-	-
4	16	19	-	-	-	-

L = Left Foot
R = Right Foot

Figure 2: The boot on the right has been worn for three, 30-minute tests through grass. The boot on the left has been coated with silicone after these three, 30-minute tests.

Figure 3: The boot on the right has been worn for three, 30-minute tests through puddles. The boot on the left has been coated with silicone after these three, 30-minute tests.

time for all runs should make the sweat from each subject's foot a constant factor in the total amount of moisture accumulated in his boots and socks. Since we were examining the gross trends in moisture accumulation, no effort was made to measure individual sweat accumulation in the boots and socks in a dry situation.

The most moisture pickup by the boots and socks was during Test 1 which was done the morning after a 11-cm rainfall - a local record for rain falling in a 6-hour period. As the ground gradually dried out for Tests 2 to 4, the amount of moisture picked up by the boots and socks diminished, although each morning the grass was covered with dew and guttated water observed on the blades of grass. It is interesting to note that for the grass tests, the subjects felt the sensation of wet feet quite early into the 30-minute test. As the grass tests progressed, the subjects feet felt wetter sooner (except for Subject 2 who later discovered a leak in his right boot where the quarter is stitched to the vamp). This was probably a valid observation since the silicone was applied to the boots before Test 1 and was not re-applied for the rest of the grass tests. This would make it easier for moisture to enter the boots as the tests progressed as more and more of the surface of the boots was worn away by the grass blades. This is confirmed by the photo of the boot after the grass tests which shows the silicone and the black pigmented finish completely removed from the toe area.

During the puddle tests, the boots and socks picked up less moisture than in the grass tests, <u>except</u> when water entered the boot through leaks (Subject 2's right boot) or through less water-resistant areas such as the tongue area (Subjects 3 and 4 in Test 5 when they intentionally walked into the hose filling the puddle). Localized wetting of the boots and socks in these areas could be readily seen when they were doffed. This localized wetting resulted in a high <u>total</u> moisture gain for that boot and sock. The wet sensation was felt at a later time in Test 5, the first puddle test, than in the grass tests. No wet sensation was felt at all for Tests 6 and 7 except for Subject 2 with his leaky right boot. It is surmised that the bulk of the moisture was being absorbed by the leather of the boots, as indicated by the low moisture gain of the socks (2-3 g), so that no wet sensation was felt by the subjects.

As it can be seen from the photo of the boots after the puddle tests, no appreciable amount of silicone had been removed from the boots.

For the grass and puddle tests, the subjects' observations of when their feet felt wet was clearly reflected in the objective weight measurements. This gives credibility to the comments of both Canadian and American soldiers that their feet feel wetter when walking through grass than through puddles.

CONCLUSION

This study confirms the opinion of combat soldiers - their feet get wetter walking through grass than through rain puddles, provided their

boots do not leak. It seems that the grass blades severely abrade the surface of the toe of the boot, removing the silicone layer and allowing moisture to enter the boot to dampen the boot, sock and thus the foot.

COMPARISON OF THE WETTING PROPERTIES OF GUTTATED WATER AND DISTILLED WATER

METHOD

To obtain guttated water, corn was planted in a flowerpot and placed under a bell jar. When the corn was about 5 cm height, guttated water was collected from the tips of its leaves with a hypodermic needle. The guttated water was stored in the refrigerator between collections. A white precipitate was observed in this cooled guttated water. If room-temperature guttated water was shaken, foaming occurred. Both phenomena indicated the presence of compounds in this water.

Before determining what these compounds were, i.e. sugars, lipids, etc., the wettability of the leather in the Boots, Combat GS, Mark III by guttated and triple distilled water (representing dew) was determined by measuring the contact angle between the water and the leather. Liquids with a high contact angle will wet a given surface less. The contact angles of the two types of water were measured at three random places on the leather as received, and then on the leather coated with silicone, "Leather Water Repellent, CF-S-630 Type 2".

RESULTS AND CONCLUSION

The results are given in Table IV.

TABLE IV

Contact Angle of the Two Liquids on Leather (degrees)

	Triple-distilled Water	Guttated Water
Leather, as received	68,74,71	90,84,87
Silicone-treated leather	102,107,107	107,108,110

For there to be any significant difference between the wettability of the two types of water, there must be a difference of at least 30° in the contact angle between the two on the same type of surface. Since this is not the case, it is concluded that there is no difference between the wetting properties of the guttated water and dew (triple-distilled water) on new leather used in the Boots, Combat GS, Mark III. Since the wetting properties of guttated and distilled water are similar, no comparison of the contact angles on grass-abraded leather was done. No further work was done to determine the exact nature of the observed compounds in the guttated water as it was considered not to be cost-effective based on the preceding null results.

OVERALL CONCLUSION

The feet of soldiers walking through wet grass do get wetter than when they walk through puddles, provided that their boots do not leak. This wetting seems to be due to the abrasion and cutting of the boot surface, in particular the toe area, by grass blades which remove the protective silicone layer and treated black surface of the boot. Guttated water does not wet new or silicone-coated leather any more than distilled water (dew) and so does not account for the excessive wetting of boots in grass.

Increasing the depth of the surface water repellency of the boot may overcome the wetting-in-grass problem perhaps at the expense of allowing sweat buildup in the boot.

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13. ABSTRACT

Studies described here show that subjects wearing combat boots and socks get their feet wetter when walking through wet grass than through puddles due to the abrasive action of the grass which cuts away the water-repellent outer layer of the boot. Further, it was found that guttated water does not wet new or silicone-coated leather any more than distilled water (dew) and so does not account for the wetting of boots in grass.

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